PROCESSING AND DISPLAY

OF ATMOSPHERIC PHENOMENA DATA

NASA FINAL REPORT

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Prepared by

Frank B. Tatom
Robert A. Garst
Lynn R. Purser

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ENGINEERING ANALYSIS, INC.

2109 Clinton Ave. W., Suite 432
Huntsville, Alabama 35805
(205)533-9391

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1. INTRODUCTION

Under contract with the Systems Dynamics Laboratory, Marshall
Space Flight Center (MSFC), during the period April 1983 to June 1984
Engineering Analysis, Inc. (EAI) has carried out a series of technical
efforts dealing with various atmospheric phenomena. Previous technical
efforts, during the period June 1982 to March 1983, dealing with the
development of the Potential in an Electrostatic Cloud (PEC) model, have
been documented elsewhere [1].

Refinements to the PEC program are discussed in Section 2 while
Section 3 deals with the development of an Apple III graphics program. The
NSSL Lightning Data Program is discussed in Section 4, followed by a
description of data reduction procedures in Section 5. Several utility
programs which have been developed are discussed in Section 6 with
references cited appearing in Section 7.

2. REFINEMENTS TO THE PEC PROGRAM

The Potential in an Electrostatic Cloud (PEC) program was developed for calculating the potential and the components of the electric field produced by the distributed charge within a cylindrically-shaped cloud model [1]. Subsequent to the development of the original program certain mathematical refinements were incorporated into the program as discussed in the subsections which follow.

2.1 PRECISE DERIVATIVE FOR HOOP POTENTIAL

The basic building block in the PEC model is the potential for a hoop, as depicted in Figure 2-1. As previously reported [1], the
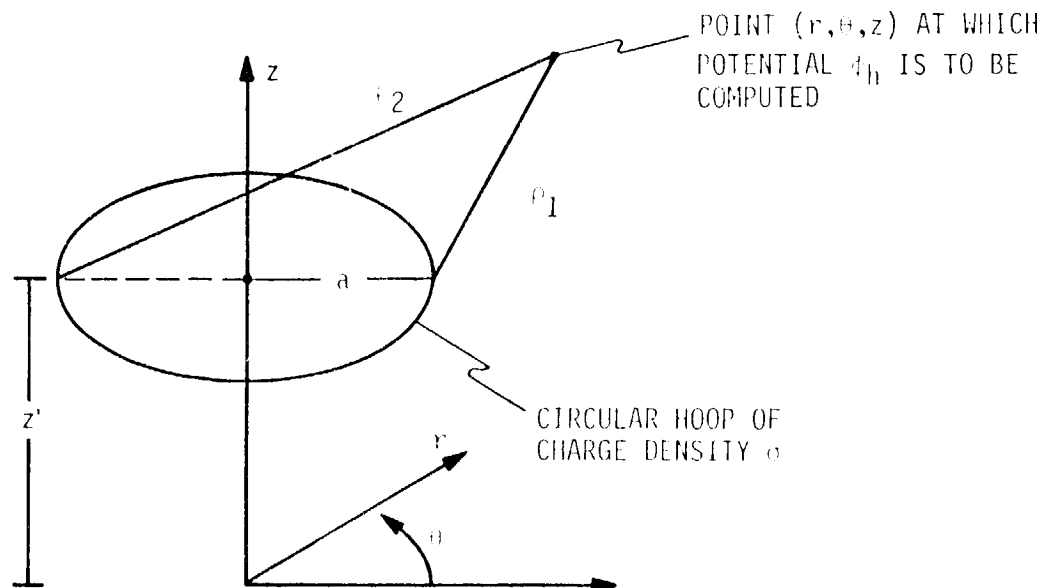
Figure 2-1. Potential of a Circular Hoop

potential for the hoop, ϕ_h, can be written

$$\phi_h = \frac{4\pi\sigma a^2}{g(\rho_1+\rho_2)} \tag{2-1}$$

where

σ = charge density

a = radius of hoop

g = geometric-arithmetic mean (gam) of m and n

$\rho_1 = \sqrt{(r-a)^2+(z-z')^2}$

$\rho_2 = \sqrt{(r+a)^2+(z-z')^2}$

m = $2a\rho_2/(\rho_1+\rho_2)$

n = $2a\rho_1/(\rho_1+\rho_2)$

Based on the definition of the gam, [2]

$$gam(m,n) = gam\left(\frac{2a\rho_2}{\rho_1+\rho_2}, \frac{2a\rho_1}{\rho_1+\rho_2}\right)$$

$$= \frac{2a}{\rho_1+\rho_2} gam(\rho_2,\rho_1) \tag{2-2}$$

Thus

$$\phi_h = \frac{2\pi\sigma a}{gam(\rho_2,\rho_1)} \tag{2-3}$$

Differentiation of ϕ_h with respect to r and z proceeds as follows:

$$\frac{\partial\phi_h}{\partial r} = 2\pi\sigma a \frac{\partial}{\partial r}\left(\frac{1}{gam}\right)$$

$$= \frac{-2\pi\sigma a}{gam^2} \frac{\partial gam}{\partial r} \tag{2-4}$$

$$\frac{\partial\phi_h}{\partial z} = 2\pi\sigma a \frac{\partial}{\partial z}\left(\frac{1}{gam}\right)$$

$$= \frac{-2\pi\sigma a}{gam^2} \frac{\partial gam}{\partial z} \tag{2-5}$$

The basic problem is to evaluate $\partial gam/\partial r$ and $\partial gam/\partial z$. Based on the properties of gam it can be shown that these derivatives can be evaluated in a manner analogous to the evaluation of gam itself as follows:

$$\frac{\partial m_0}{\partial r} = \frac{\partial \rho_2}{\partial r}$$

$$= \frac{r+a}{\rho_2} \tag{2-6}$$

$$\frac{\partial n_0}{\partial r} = \frac{\partial \rho_1}{\partial r}$$

$$= \frac{r-a}{\rho_1} \tag{2-7}$$

$$\frac{\partial m_i}{\partial r} = \frac{1}{2}\left(\frac{\partial m_{i-1}}{\partial r} + \frac{\partial n_{i-1}}{\partial r}\right) \tag{2-8}$$

$$\left. \begin{array}{c} \\ \\ \end{array} \right\} \quad (i > o)$$

$$\frac{\partial n_i}{\partial r} = \frac{\partial}{\partial r}\sqrt{m_{i-1}\, n_{i-1}} \tag{2-9}$$

$$\frac{\partial m_0}{\partial z} = \frac{\partial \rho_2}{\partial z}$$

$$= \frac{z-z'}{\rho_2} \tag{2-10}$$

$$\frac{\partial n_0}{\partial z} = \frac{\partial \rho_1}{\partial z}$$

$$= \frac{z-z'}{\rho_2} \tag{2-11}$$

$$\frac{\partial m_i}{\partial z} = \frac{1}{2}\left(\frac{\partial m_{i-1}}{\partial z} + \frac{\partial n_{i-1}}{\partial z}\right) \tag{2-12}$$

$$\left. \begin{array}{c} \\ \\ \end{array} \right\} \quad (i > o)$$

$$\frac{\partial n_i}{\partial z} = \frac{\partial}{\partial z}\sqrt{m_{i-1}\, n_{i-1}} \tag{2-13}$$

This sequence converges rapidly to the desired derivatives $\partial gam/\partial r$ and $\partial gam/\partial z$.

The preceeding equations were coded and incorporated into the PEC program, replacing the code for the previously used central finite difference approximation method for calculating derivaties.

2.2   CORNER POINT CALCULATION METHOD

An improved method was developed for calculating the potential and the electric field for the electrostatic cloud model. With the improved method the cloud is divided into an array of rectilinear cells in the r-z plane. Each cell contains a single potential hoop which coincides with the cell center. For a specified point inside the cloud, the potential and its derivatives are calculated at four points, corresponding to the corners of the cell containing the specified point. Then, double linear interpolation is utilized to calculate the values for the specific point. This method, which eliminated occasional erroneous values generated by the previous method when the given point was located very near one of the hoops, has been incorporated into the current version of the PEC program.

3. APPLE III GRAPHICS PROGRAM

A Pascal program was developed for generating plots on the Apple III for continuous x-y data. This program, which is used for the study of lightning data, has the following capabilities:

1) the ability for the user to pick an initial density of data points for viewing any portion of the data,

2) the ability to scroll right or left for viewing the next section of continuous data or the section immediately preceeding the current viewing area,

3) the ability to change the point density at any time for creating enlargements of a particular section of data beginning at any point,

4) the ability for complete labeling of the x- and y-axes as well as the label for the plot description,

5) the ability to save onto disk any currently viewed plot of any desired section of the data, and

6) display a map of the local region.

In addition, the following statistical information is also displayed:

1) the map range,

2) the date,

3) the time of the first event,

4) the time of the most recent event,

5) the screen refresh time (after which time the screen will automatically clear all previous lightning strikes and statistical information and begin again),

6) any inoperable direction finders,

7) the total number of positive strikes detected and the total number of positive strikes plotted on the given map area,

8) the total number of negative strikes detected and the total number of negative strikes plotted on the given map area.

The system includes a real-time data acquisition capability via

the Apple III's RS-232 port. Included among the lightning data, which are
read in, are the latitude and longitude of the lightning strike, and the
exact time that the event occurs, as well as its polarity. Other user
options included in the program are as follows:

1) the mode (color or black and white),
2) the color choices (if color),
3) the option to create a hard copy of the screen information on
   a "Silentype" (thermal) printer,
4) the option to write the actual lightning data information to
   disk, and
5) the option to display all or any of a user-defined sector of
   the chosen map area.

Two versions of the program exist; one for North Alabama and the other for
Oklahoma, as discussed in the subsections which follow.

3.1   THE NORTH ALABAMA LLP DATA ACQUISITION AND DISPLAY SYSTEM

        For this version the user may choose from one of two maps of the
North Alabama area to use with the display system. These maps are of radii
100 km and 230 km, respectively, centered around the Huntsville Weather
Service station located near the Huntsville Jetport.

        The North Alabama system includes the ability to display a number
of available blocks on the data storage diskette. In addition, the program
reads back the stored lightning data from disk and plots the data on the
same map system. This is done using an accelerated time option in which the
time between each plotted lightning strike is some user-selected factor of
the actual time between strikes (i.e., an actual time difference of six
minutes with a factor of three would plot with a two-minute delay).

3.2   OKLAHOMA LLP DATA ACQUISITION AND DISPLAY SYSTEM

        A special version of the program for displaying LLP lightning data
was developed for use by the National Severe Storms Laboratory in Norman,

Oklahoma. The user may choose from one of two maps of the Oklahoma area to use with the display system, each centered around the Oklahoma City Weather Service station.

At the request of the National Severe Storms Laboratory (NSSL), an option for excluding the cities from the display maps was incorporated into the code. The data points comprising the range rings for the Oklahoma maps were calculated and stored to disk so that they, like the maps, are initially read into the program. The lightning strikes and statistical information for each of the two Oklahoma maps (80 km and 115 km) are currently being generated by the program.

4. NSSL LIGHTNING DATA PROGRAM

This program generates an x-y plot of lightning strikes over a
given period of time, sums the number of occurrences in pre-determined unit
areas, and then generates a contour plot based on the calculated
frequencies. The basic purpose of the program is to correlate lightning
strike locations with storm cells position(s).

The basic approach in the development of the program involved
computing the number density of strikes (per unit area) and generating
contour maps representing lines of constant number density. The EAI contour
plotting routine was incorporated into existing software to generate the
necessary contour plots. In plotting contours two options exist as follows:

1) a user-specified number of contours are plotted with the
   values of the contour being equally spaced between the
   maximum and minimum values, and

2) a user-specfied number of contours are plotted with
   user-specified values assigned to each contour.

As part of the procedure for using the program, raw NSSL lightning
data is read from magnetic tape, reformatted, and then stored on disk by
means of a separate program, SDATA. The reformatted data are then read from
disk by the NSSL Lightning Data program.

The program has been used to generate lightning strike contours
covering portions of Oklahoma, Texas, Arkansas, Missouri, and Kansas.
Examples of contours produced are provided in Figure 4-1 which corresponds
to one 15-minute interval between 2015 and 2030 on May 27, 1982. The unit
cell size used for computing number densities was 0.1 degree latitude by 0.1
degree longitude. Figure 4-2 provides a plot of the actual lightning strike
locations upon which the contours were based. The transient behavior of the
contours is illustrated in Figure 4-3, which consists of four plots corres-
ponding to four successive 15-minute intervals.

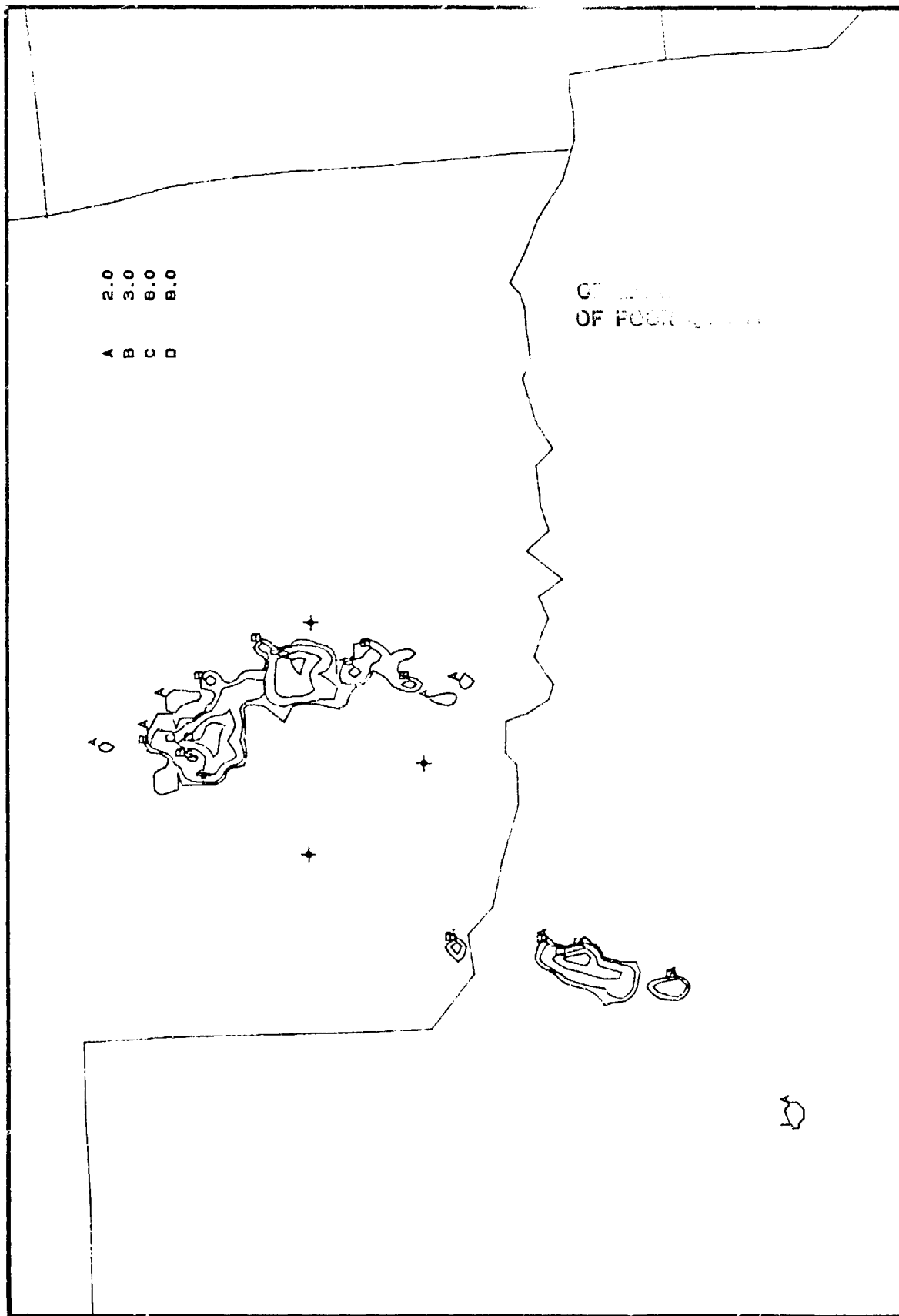A 2.0
B 3.0
C 6.0
D 8.0

OF POOR

Figure 4-1. Example Lightning Strike Contours for 15-Minute Interval, 2015-2030, May 27, 1984.
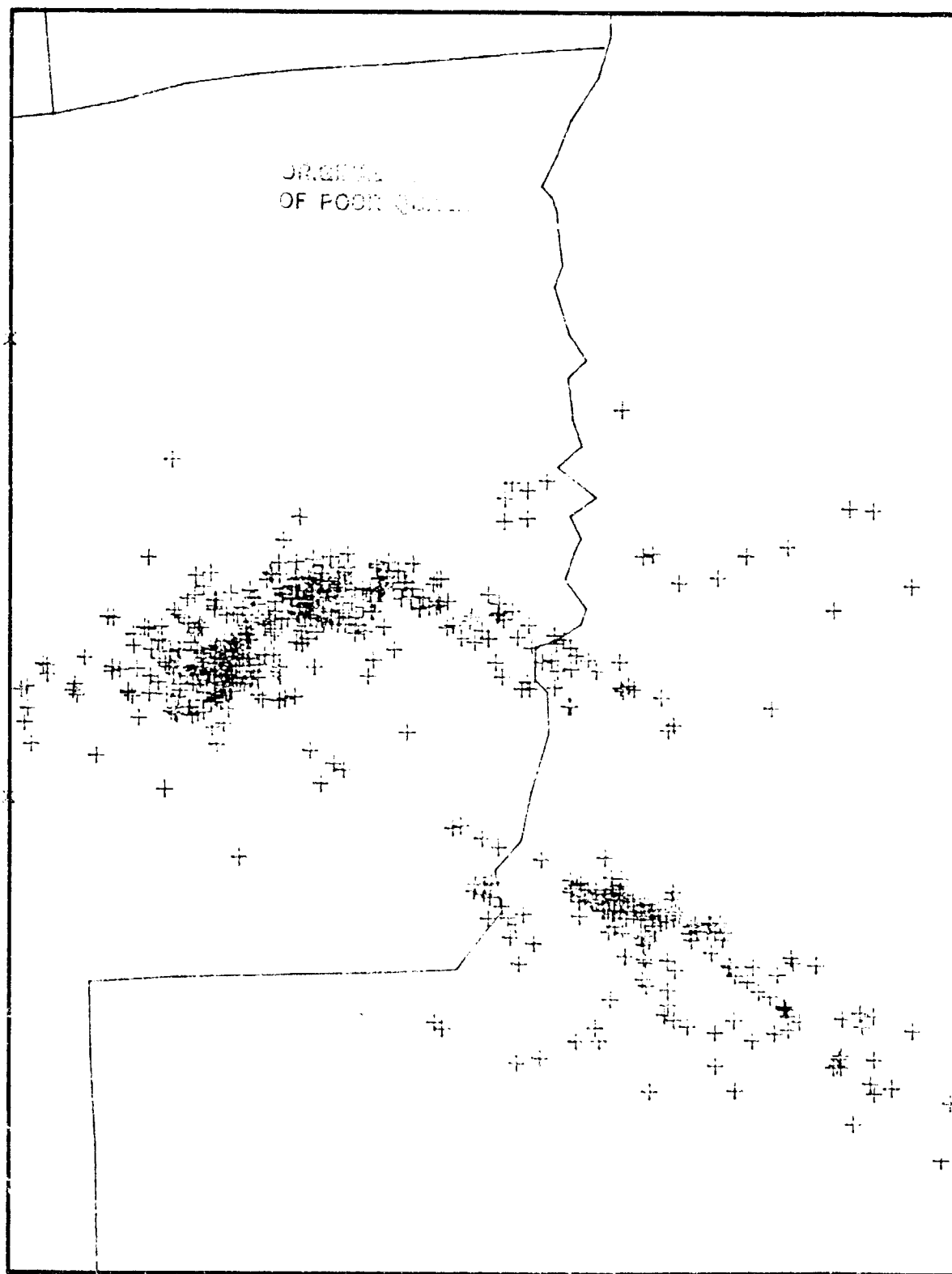
Figure 4-2. Lightning Strike Plot for 15-Minute Interval, 2015-2030, May 27, 1984.
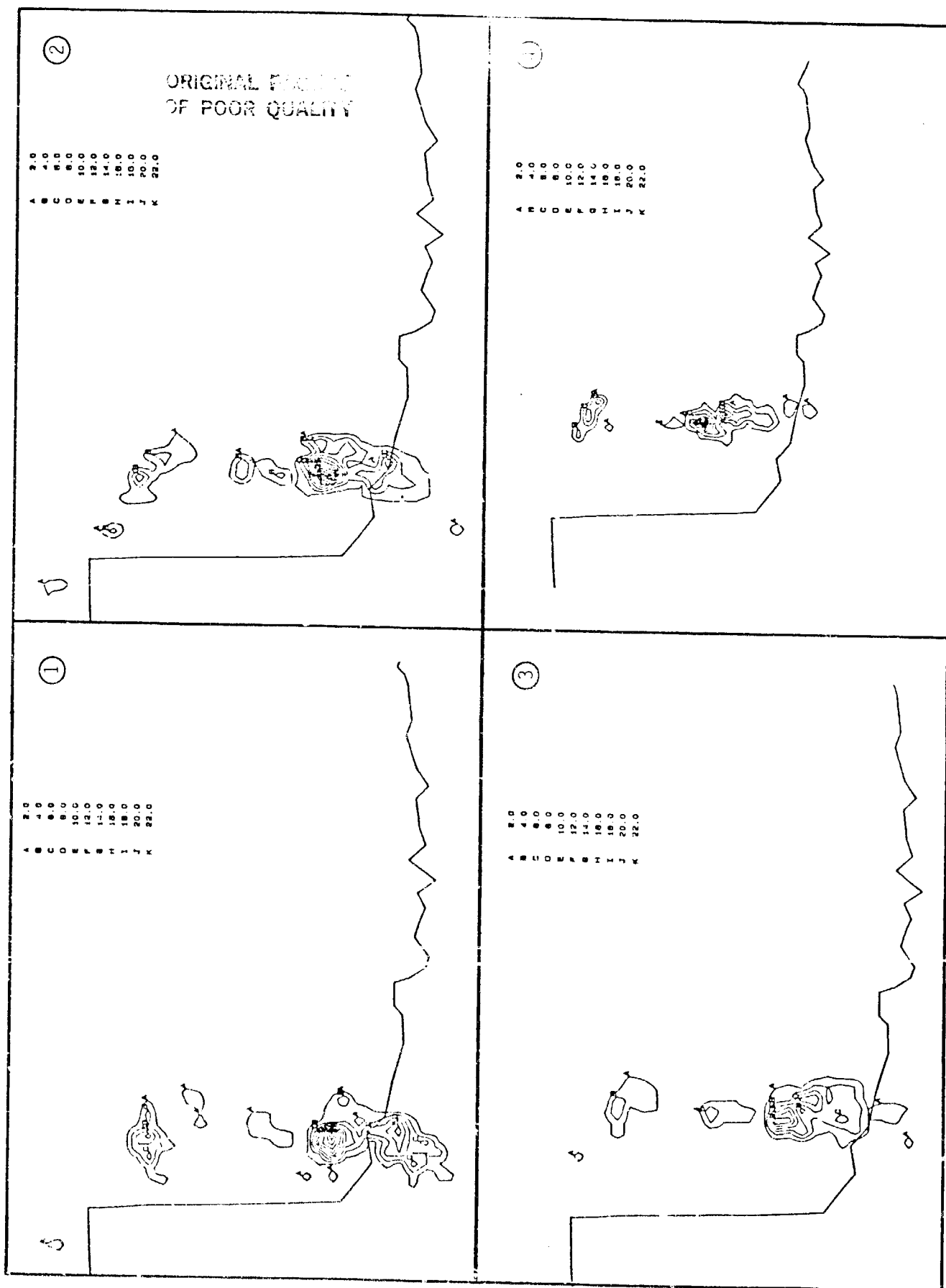
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Figure 4-3. Example Lightning Strike Contours During Four Successive 15-Minute Intervals.

5. DATA REDUCTION PROCEDURES

Several different data reduction procedures were developed as covered in subsequent subsections.

5.1   WORK WITH SPECTROMETER DATA

Spectrometer data were transferred from the HP 1000-L computer to the HP 1000-F computer and then reformatted to eliminate erroneous data from the so-called "blanking periods". Subsequent plots of the data were generated and efforts were made in the area of filtering the data for noise reduction.

5.2   IMPLEMENTATION OF FILTERING METHODS

Five different methods for noise reduction filtering were encoded and included in the program for plotting spectrometer data. The program allows the user the option of choosing any or all of the filtering processes for each individual output. Multiple plots were generated for comparison of the effects of these different methods and their combinations.

5.3   WORK WITH LOW-GAIN OPTICAL PULSE SENSOR (OPS) DATA

Raw low-gain OPS data were obtained from flight tape and processed and stored on hard disk in digital form. The data were transferred via magnetic tape to the HP 1000-F computer. All data records (4 K data per record) indicated substantial activity had been plotted. Some effort was also expended pertaining to a statistics program for working with processed OPS data.

5.4   SORTING PROGRAM

A sorting program was written which takes previously analyzed lightning data and separates them into two files according to intra-cloud or cloud-to-ground events. Furthermore, for cloud-to-ground events the program

allows the user to separate the data into three additional files according to first return, subsequent strikes, and a collector file.

6. UTILITY PROGRAMS

In conjunction with the various software development efforts described in the preceding sections, several general-purpose programs were developed as discussed in the subsections which follow.

6.1 LEAST SQUARE PROGRAM

A program was developed to calculate and plot, for a set of x-y data points, a curve based on the least squares method. The program contained certain special features as follows:

1) the ability to read any user-specified data file,
2) the ability to calculate equations of higher degree (up to sixth degree), and
3) the capability of user-specified x- and y-axis labeling.

6.2 WORK ON LATITUTDE-LONGITUDE CONVERSION PROGRAM

A previously provided latitude-longitude conversion program was adapted to handle several specific map projections of north Alabama and its surrounding area. The x-y coordinate system upon which the program is based was correlated to the x-y coordinate system of one of the digitized maps, thereby permitting the conversion of a given latitude and longitude position to its proper x-y coordinate position on the digitized map, and vice versa.

6.3 PROGRAMS FOR DATA CONVERSION TO APPLE III PASCAL

Many of the data files on the HP 1000-F are stored in binary and fixed-length random access files. In order to transfer the data to another system, a program was written to read the data and convert to a non-binary variable-length sequential access file on the HP 1000-F. The resultant files are available to be transferred (in ASCII form only) through remote accessing to an Apple III microcomputer. An additional general-purpose Pascal program was written which

1) reads the data from the ASCII file,

2) determines the number of columns of data and the classi-
   fication as to the type and form of data: integer, real
   (floating point), or real (scientific notation), and

3) transfers each type of data from its ASCII representation into
   a Pascal data file.

7. REFERENCES

1. Garst, Robert A., and Frank B. Tatom, "Potential in an Electrostatic Cloud (PEC) Model, User's Manual", EAI-TR-83-001, Engineering Analysis, Inc., Huntsville, Alabama, March 1983.

2. MacMillan, William Ducan, The Theory of the Potential, Dover Publications, New York, N. Y., 1958.